APPARATUS FOR SEISMIC DATA ACQUISITION

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 12/220,518, filed Jul. 25, 2008, now U.S. Pat. No. 7,668,047, which is a divisional of U.S. patent application Ser. No. 10/766,253, filed Jan. 28, 2004, which claims priority to and the benefit of U.S. Pat. No. 7,561,493, filed on May 30, 2003, all of which are hereby incorporated by reference.

BACKGROUND

The present invention relates to the field of seismic exploration. More particularly, the invention relates to a method and apparatus for seismic exploration, and most particularly to a self-contained, land based or marine deployable seismometer system.

Seismic exploration generally utilizes a seismic energy source to generate an acoustic signal that propagates into the earth and is partially reflected by subsurface seismic reflectors (i.e., interfaces between subsurface lithologic or fluid layers characterized by different elastic properties). The reflected signals (known as "seismic reflections") are detected and recorded by seismic receivers located at or near the surface of the earth, thereby generating a seismic survey of the subsurface. The recorded signals, or seismic energy data, can then be processed to yield information relating to the lithologic subsurface formations, identifying such features, as, for example, lithologic subsurface formation boundaries.

Typically, the seismic receivers are laid out in an array, wherein the array consists of a line of stations each comprised of strings of receivers laid out in order to record data from the seismic cross-section below the line of receivers. For data over a larger area and for three-dimensional representations of a formation, multiple single-line arrays may be set out side-by-side, such that a grid of receivers is formed. Often, the stations and their receivers are remotely located or spread apart. In land seismic surveys for example, hundreds to thousands of receivers, called geophones, may be deployed in a spatially diverse manner, such as a typical grid configuration where each line extends for 5000 meters with receivers spaced every 25 meters and the successive lines are spaced 500 meters apart.

Generally, several receivers are connected in a parallel-series combination on a single twisted pair of wires to form a single receiver group or channel for a station. During the data collection process, the output from each channel is digitized and recorded for subsequent analysis. In turn, the groups of receivers are usually connected to cables used to communicate with the receivers and transport the collected data to recorders located at a central location, often called the "dog house." More specifically, when such surveys are conducted on land, cable telemetry is used for data transmission between the individual receivers, the stations and the dog house. Other systems use wireless methods for data transmission so that the individual receivers and stations are not connected to each other. Still other systems temporarily store the data at each station until the data is extracted.

As used throughout this description, "land-based seismic systems" shall include seismic systems utilized in costal transition zones such as shallow water or marshes. With respect to operation of most land-based seismic systems, the prior art generally requires some externally generated control command in order to initiate and acquire data for each shot, cause stored seismic data to be transmitted back to the dog house and cause any other data, such as quality control data, to be transmitted back to the dog house. Thus the seismic receiver units must be either physically connected to the central control recording station or "connectable" by wireless techniques. As mentioned above, those skilled in the art will understand that certain environments can present extreme challenges for conventional methods of connecting and controlling seismic, such as congested or marine environments, rugged mountain environments and jungles or remote desert locations. Difficulties may also arise in instances where the interconnected, hard-wired receiver array must be periodically moved to cover a larger area.

Whatever the case, each type of connection, whether via a physical cable or through wireless techniques, has its own drawbacks. In cable telemetry systems, large arrays may result in large quantities of electrically conductive cabling that are expensive and difficult to handle, deploy or otherwise manipulate, as well as repair and maintain. In hostile environments characterized by extreme or corrosive conditions, such as salt water, hot, sandy deserts or overgrown, damp jungles, costly cable armoring may be required. Furthermore, conventional cabling also requires a physical connection between the cable and the sensor unit. Since it is generally not practical to hard wire strings of receivers to a cable, the more conventional technique is to use external cabling and connectors between strings of receivers and the telemetry cable. This point of the connection between the cable and the sensor is particularly vulnerable to damage, especially in extreme or corrosive environments. Of course, with systems that are physically cabled together, it is much easier to provide power to the stations/units, to synchronize data acquisition with the shot time, to perform quality control checks and to otherwise control the units.

It should be noted that whether for cabled or wireless systems, the seismic recording systems of the prior art separate the receiver package, i.e., the geophones, from the radio control package and/or the recording package of the units to the extent the units provide any on-board recording. It has heretofore been conventional thinking in the prior art that geophone coupling with the earth can be maximized in this way. External cabling is required in these prior art systems to connect the geophone package of a unit with the recording and/or radio telemetry packages of the unit. As such, many of the aforementioned drawbacks that arise from cabling system units together also exist when cabling various package components of an individual unit to one another.

In cases where either wireless technology is utilized or operation of units and their sensors is through pre-programming, control and monitoring of the units and sensors becomes more difficult. For example, ensuring that recording is synchronized with the shot timing is crucial since the individual sensor units are not wired together as described above. Hence the need for accurate on-board clocks as mentioned above. In this regard, activating each unit for sensing and recording at the appropriate time must coincide with the shot. One common prior art technique in this regard is to utilize a command signal sent from the control station to power up the system, initiate transmission of data stored from the previous shot and initiate collection of data for the current shot which